Inner Space in Outer Space

A Virtual Astronaut Teacher's Guide to
The Human Body in Outer Space

www.virtualastronaut.jsc.nasa.gov

Created by Futron Corporation for NASA Johnson Space Center, 2001

Table of Contents

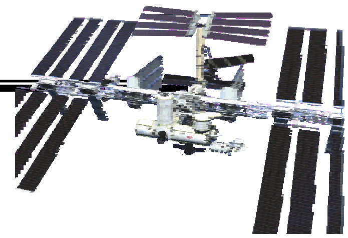
Introduction

High above the earth, orbiting at an altitude of 200 nautical miles and a speed of more than 17,000 miles per hour is the International Space Station (ISS), the next step in our exploration of space. As the permanent home to a crew of astronauts, cosmonauts, and scientists, the ISS will allow NASA and other space agencies, along with universities and private industry, to conduct research in a wide variety of areas, from physics and chemistry to cosmology and biotechnology. ISS research will not only help us to send astronauts on far-reaching journeys to other planets, but will also help us improve the quality of life for all of us below on Earth.

Some of the most important research conducted on the ISS will be in the field of human physiology. As we will see, the human body undergoes a number of changes when it is exposed to microgravity. Research on the ISS will investigate these changes—why they happen and how we might limit or prevent them. As we do this, we will begin to understand even more about how the human body works on Earth, helping us fight disease and improve the health of all humans.

This Teacher's Guide will let teachers and students explore the same aspects of human physiology studied on board the ISS. You will learn about the different systems of the human body: how they work on Earth and how they change in microgravity. You will have the opportunity to conduct your own space research—right in your classroom.

The Skeleton



Introduction

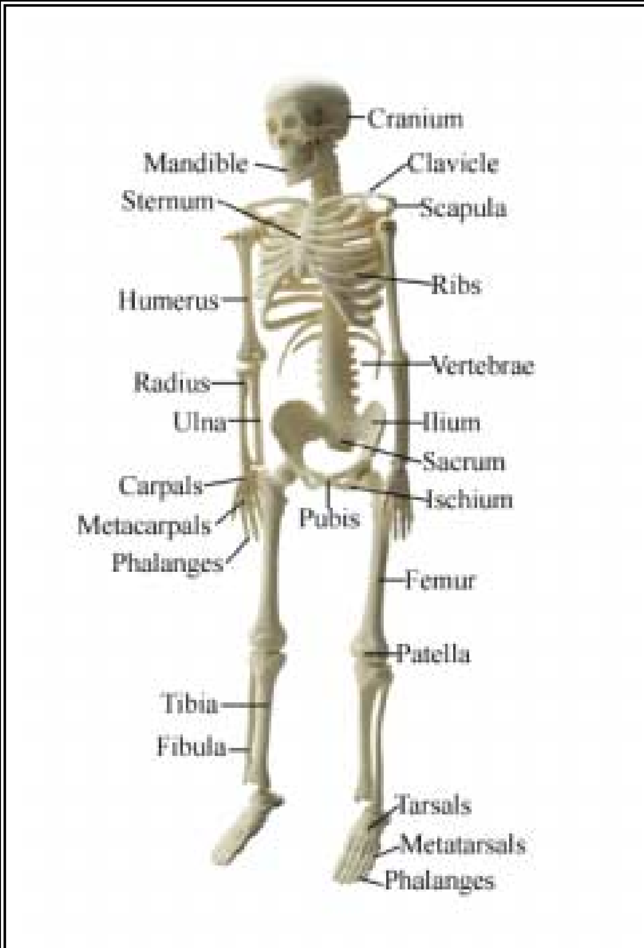
Think about the human body. Now compare it to the body of animals you have seen. Do you notice anything different? The human body is the only one that supports an upright, or *bipedal*, form of locomotion. Over millions of years, the bones of the skeleton have developed in a way that allows us to walk upright on two legs and function against the pull of the Earth's gravity.

What happens, then, when we leave this source of gravity? Once on orbit, astronauts live in **microgravity**: the force of gravity is much, much weaker (virtually zero), and the body no longer needs to counteract it. As a result, the body adapts to its new microgravity surroundings. The changes to bone in particular hold consequences for astronauts once they return to Earth.

Before we can understand how and why bone changes in microgravity, we need an understanding of how bone works on Earth.

Bone on Earth

The 206 bones in the human body come in many sizes and shapes. One of the largest bones of the body, the femur, can be over a foot long, while some of the smallest bones in the body—the pisiform bone in the wrist, or the stapes in the inner ear—are no bigger than a pea.



What do your bones do for you? The first answer that you might come up with is "Bones support my body"—and you would be correct. The skeletal system provides the framework for the human body—and much more. We rely on our bones for many things:

- Support and protection: Bones are an essential component of the body's support system. The skeleton anchors soft tissues like organs, muscles, ligaments, and tendons. It also supports the weight of these tissues. It is easy to visualize the skeleton as the concrete support structure of a building. Just like the concrete of a building protects its inhabitants from the outside elements, the skeleton also protects some of our most vital organs. The thick bones of the skull, for instance, protect the brain. Without this protection, the internal organs would be in danger of injury from slight bumps and falls.

- <u>Storage</u>: The skeleton houses several sources of nutrition and energy. Bone contains **yellow marrow**, where the body stores a reserve of fat cells. These fat cells can be utilized when the body needs a supply of energy. In addition to fat, bones also store essential ions, like calcium, phosphate, hydrogen, potassium, and magnesium. These minerals are used in many systems of the body for a wide range of processes.

- <u>Cell Production</u>: The skeleton is also responsible for the production of blood cells. The soft spongy tissue inside bone called **red marrow** manufactures **red blood cells**, which transport oxygen throughout the body, and **platelets**, which help the clotting process.

- <u>Movement</u>: The skeleton also plays an important role in our ability to walk, jump, sit, stand, and run. In order to create movement, our muscles operate a system of levers—our bones. Without these levers, the muscles will not move.

The structure of bone gives it the strength to protect and support our bodies and the flexibility to absorb the forces generated by some types of movement. The combination of strength and flexibility comes from the **composite** structure of bone. This means that it has both an organic component and an inorganic component. The organic component is composed mainly of **collagen**, long chains of protein that intertwine in flexible, elastic fibers. Collagen is also so strong that a single fiber only one millimeter in diameter can support the weight of a 10-*kilogram* load. **Hydroxyapatite,** the inorganic component, is a calcium-rich mineral that stiffens and strengthens the collagen. Together, the interwoven organic and inorganic components of bone create a sturdy yet flexible skeletal structure able to support the body, absorb the shock of movement, counteract the pull of gravity, and allow us to move.

Bone is a dynamic material; it is constantly changing throughout our lives. The **remodeling** process replaces old bone with healthy new material and also helps heal fractures and breaks. The remodeling process involves three types of cells: osteoblasts, osteocytes, and osteoclasts. **Osteoblasts** form new bone. These cells synthesize and deposit bone material. **Osteocytes**, which are actually mature osteoblasts, maintain mature bone tissue. The third type of bone cell, **osteoclasts**, **resorb** or "eats" older bone tissue. As the calcium in mature bone ages, osteoclasts begin to resorb it, leaving a tiny tunnel. About three weeks later, when they are finished with their meal, the osteoclasts disappear, and osteoblasts enter the tunnel. The osteoblasts redeposit new calcium, leaving the bone healthy and strong. The osteoblasts mature into osteocytes and become embedded in the bone. The bone continues to age and the remodeling process starts again.

The key to the remodeling process is that osteoblasts and osteoclasts work at an equal rate. Osteoblasts lay down the same amount of new bone as the osteoclasts resorb. If the body were to absorb too much calcium from bones (if osteoclasts work faster than osteoblasts), the skeleton would become thin and weak. Consequently, a healthy body never loses more calcium than will be replaced, and the bones maintain a constant strength. As we are about to see, however, exposure to microgravity changes this balance.

Bone in Space

Bone begins to change after an astronaut has lived in microgravity for only a few days. Microgravity reduces the amount of weight that bones must support to almost zero. At the same time, many bones that aid in movement are no longer used as much as they are on Earth. For example, microgravity allows astronauts to “float” effortlessly in one position, so they do not have to use the bones in their legs, hips, or back to sit or stand. When a bone is not used, a biomechanical trigger causes calcium normally stored in the bones to be broken down and released into the bloodstream. This decrease in bone mass density is called **osteoporosis**. Osteoporosis leaves bone weak and less able to support the body's weight and movement upon return to Earth, placing the astronaut at a higher risk of fracture.

Bone loss begins within the first few days in space. Some astronauts who spent months aboard the Russian space station *Mir* lost as much as 20% of their bone mass. The most severe loss occurs between the second and fifth months in space, although the process continues throughout the entire time spent in microgravity. The exact mechanism that causes the loss of calcium in microgravity is unknown. Many scientists believe that microgravity causes osteoclasts to resorb bone much faster than osteoblasts lay down new bone. The exact trigger for this change has not been found.

Astronauts do not feel the effects of bone loss while they are in space, but they are affected upon their return to Earth. When the force of gravity returns, the skeleton may no longer be strong enough to support the body’s weight or counteract gravity. This leaves astronauts at a much higher risk of bone break or fracture.

Microgravity-induced osteoporosis is a serious matter, so doctors and scientists are researching ways to limit or prevent bone loss in astronauts. Throughout the history of space flight, astronauts have always done special exercises to keep their muscles and bones strong. In addition, flight surgeons make sure that astronauts receive dietary and vitamin supplements that give them added protection against bone loss. In the future, it is possible that new types of exercises, diets, or even medication may prevent bone mineral loss—in astronauts and in people on Earth.

Activity #1: Bag of Bones

Objective
Following this activity, the student will be able to
- Identify the effects of decreased bone mass (osteoporosis)
- Describe why healthy bones are important in space and on Earth

National Science Standards
Unifying Concepts and Processes in Science
- Evidence, models, and explanation
- Change, constancy, and measurement

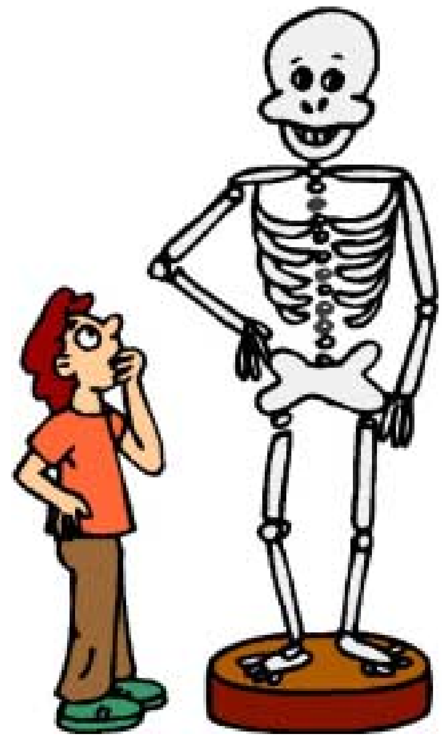
Form and function

Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Life Science
- Structure and function in living systems
- Diversity and adaptations of organisms

Science in Perspective
- Personal health

History and Nature of Science
- Nature of science



National Mathematics Standards
- Mathematics as problem solving
- Mathematics as reasoning
- Mathematical connections
- Computation and estimation

Materials Needed
- Corn puff cereal (approx. 4.5 oz. per group)
- Ziplock snack bags (6 5/8 inch x 3 ¼ inch) - 5 per group (larger bags hold too much cereal to count in a reasonable amount of time)
- Permanent markers for labeling bags
- Heavy books (one per group)
- Student Activity Guide (one per student)
- Broom and dustpan (for clean-up)

Time Required
This activity may be spread out over a two- or three-day period. You may wish to use the first day for discussion and baggie preparation, and the second and third days for experimentation, data collection, and discussion.

Procedure

1. Begin with a discussion of osteoporosis. Ask students if they know anyone—grandparents, for example—who suffers from osteoporosis. Do they know what osteoporosis is? Do they know what causes it?
2. Explain to students that astronauts experience a particular kind of osteoporosis. Describe the effects of microgravity on bone.
3. Tell the students that they are going to investigate bone loss and the effects that it may have. To do this, they will use baggies and cereal to make their own "bones." Explain that each baggie will represent a bone, and the cereal inside the bone will represent the calcium and cells that make the bone strong. Removing cereal from some of the bags will simulate a bone that has lost some of its mass.
4. Distribute cereal, snack bags, and worksheets to students. In order to expedite the experiment, students should work in groups of four; the group can work on Bag 1 together, and then each student is responsible for one additional bag.
5. Students should follow the directions on the worksheet. <u>Note about cereal smashing</u>: some of the cereal has natural holes in it. Explain to students that they should examine the cereal *before* smashing it, so that they have a reference point when counting unaffected pieces after the smashing step. In addition, *one* student should be responsible for smashing *all* of the bags, so that the amount of force will be the same on each bag. Discuss what students should look for when they are counting "affected" pieces of cereal. Pieces that have dust (from other smashed pieces) or only a tiny flake taken off should not be counted as "affected."
6. After the students have completed the activity, bring the group back together. Ask each group to share their results with the class. Discuss the results and the follow-up questions.
7. If some groups' results did not come out as expected (i.e., density did not drop), discuss the possible reasons for this. Answers may include miscounting, uneven force applied when smashing bags, etc. Can students think of another way to test their hypotheses?

Extensions

1. Have students graph the data from their investigations to explore the relationship between bone density and amount of damage.
2. Compare group outcomes to demonstrate that results always vary—and are often unexpected. Emphasize that science is often indefinite, but always involves *systematic* study.
3. Investigate other risk factors for osteoporosis, including health, ethnicity, age, etc. Explore ways in which students can change their lifestyles now so that they may avoid osteoporosis in the future.

Assessment

Student worksheets and classroom discussion may be used for assessment.

Bag of Bones

Osteoporosis is a loss of bone mass. It makes bones weak and fragile, which can make it very easy to fracture or break a bone. Low bone mass can be a problem throughout a person's life, but it may not be until late in life that full-blown osteoporosis develops. In fact, many people do not realize that they have osteoporosis until one of their bones fractures after a minor slip or fall.

Osteoporosis is a big problem in the world today. In the United States alone, two million men and eight million women have osteoporosis, and another eighteen million men and women are at risk for this disease. It is not limited to one group of people, either. As many as 50% of Caucasian and Asian women are at the highest risk. More than ten percent of Hispanic and African-American women also run the risk of osteoporosis.

Astronauts who spend more than a week in space also suffer from a form of osteorporosis. This type, called **disuse osteoporosis**, occurs when astronauts do not use their bones in space in the same way that they do on Earth. For example, the bones used in standing and walking on Earth are not used nearly as much in space, because astronauts spend much of their days "floating" and propelling themselves with their arms. By the end of their mission, astronauts lose bone mass in their legs and hips, which leaves them at risk for fracutures and breaks when they return to Earth's gravity. Although astronauts eventually regain most of their bone mass, they may not fully recover. It is important, both for future astronauts and for our health here on Earth, that researchers learn all that they can about why osteoporosis occurs, and how we can prevent it.

Using every-day bags and cereal to represent bone, and a heavy textbook to represent an unexpected force (like a bump or a fall), you will see how low bone mass affects bone, and why it is important that astronauts and people on Earth do everything they can to prevent osteoporosis.

Get Ready

- 5 snack bags
- Corn puff cereal
- A very heavy book (like a dictionary)
- A broom and dustpan (for clean-up)
- Permanent marker
- Pen or pencil

Think about it

- Why is it important to have strong, healthy bones?

- What will happen if your bones become weak?

Formulate your hypothesis

What do you think will happen to a bone (in this case, represented by your baggie and cereal) if force is suddenly applied to it? Will the results change if the bone is progressively weakened?

Collect the data and test your hypothesis

1. Using a permanent marker, label the bags 1-5.

2. Bag 1 will represent a healthy bone on Earth. To build a "bone" you will use pieces of cereal to represent individual units of bone mass. Fill the bag with enough cereal so that the bag is very full and there is very little air in it, but not so full that you cannot close it. Keep track of how many pieces of cereal you put into the bag, and record this on your worksheet as **Normal Bone Density.** Close the bag, and make sure it is closed *tightly*—otherwise you may wind up with a very big mess!

3. To represent a bone that has lost mass as a result of spaceflight or aging, you now need to fill each bag with less cereal, or bone mass, than is in Bag 1.
   Bag 1: 0% bone loss (normal bone)
   Bag 2: 90% of original bone remains; 10% original bone lost
   Bag 3: 80% of original bone remains; 20% original bone lost
   Bag 4: 65% of original bone remains; 35% original bone lost
   Bag 5: 50% of original bone remains; 50% original bone lost

To calculate the amount of cereal you need in Bag 2, you will need to calculate 90% of **Normal Bone Density**. Fill Bag 2 with this amount. This represents a loss of 10% of the bone mass.

4. Use a similar method to calculate 80%, 65%, and 50% of the Normal Bone Density, and fill Bags 3, 4, and 5 with these amounts. Record the amount of bone left in each bag on your worksheet.

5. Now you are ready to see what effects a sudden force may have on weakened bones. Place Bag 1 on a hard surface. Then, quickly and carefully, but forcefully, smash the heavy book onto the bag. Again using the same amount of force, smash the remaining bags.

6. What happened to your bones? Count the number of *unaffected* cereal pieces left in each bag, and record this on your worksheet.

7. How much of the bone was unaffected? To calculate this, use the formula below and record your values on your worksheet.

$$\left[\begin{array}{c}\#\\ \text{unaffected}\\ \text{remaining}\\ \text{in the bag}\end{array} \div \begin{array}{c}\text{original}\\ \text{density of}\\ \text{the bag}\end{array}\right] \times 100$$

8. How much of the bone was affected? To calculate this, subtract the Unaffected Bone value from 100%. Record your values on your worksheet.

Bag of Bones Worksheet

Normal Bone Density=__________ pieces of cereal in Bag 1
Density of Bone 2 = 90% of Bag 1 = ________ pieces of cereal
Density of Bone 3 = 80% of Bag 1 = ________ pieces of cereal
Density of Bone 4 = 65% of Bag 1 = ________ pieces of cereal
Density of Bone 5 = 50% of Bag 1 = ________ pieces of cereal

Before the Experiment			After the Experiment		
Bag	Bone Loss Represented	Density (# of cereal pieces in bag)	# of unaffected pieces	% of bone unaffected	% of bone affected
1	0%				
2	10%				
3	20%				
4	35%				
5	50%				

Analyze the results

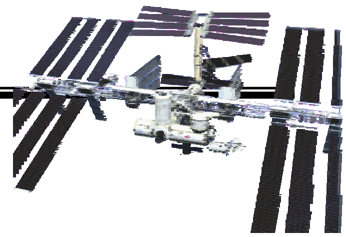
What happened as the amount of cereal decreased?

Now imagine that your baggie bone is actually a real bone. If a real bone were built like your baggie bone, what would happen if a sudden force (like a bump or fall) were applied to the bone?

Do your findings support your hypothesis? Why or why not?

How do you think we can prevent bone loss?

Muscle



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Background

The word "muscle" conjures the thought of movement. While it is true that movement would be impossible without our muscles, muscles are involved in much more. In addition to helping us maintain our bipedal posture, muscles allow the eyes to move and focus, the throat to swallow, the lungs to inhale and exhale, blood to circulate, and the heart to beat. In short, our muscles allow us to live.

Like bone, muscle is also a complex tissue that has developed in the presence of gravity. As a result, some muscles are affected once an astronaut reaches orbit, and the force of gravity disappears. In this section, we will examine the effects of microgravity on skeletal muscle. Before examining the reaction of muscles to microgravity, however, it is useful to first look at muscles on Earth. What do they do? How do they do it?

Muscle on Earth

Skeletal muscle plays several important roles in the human body:

- Locomotion and movement: Our muscles allow us to interact with our environment and respond to the unexpected. Our leg muscles, for instance, are key players in **locomotion**, or how we move around in the environment.
- Posture and joint stabilization: Skeletal muscle is necessary to maintain our posture. The leg and back muscles in particular allow us to remain upright against the pull of Earth's gravity. The skeletal muscles also stabilize the joints.
- Heat production: Muscles are responsible for producing body heat. Although we do not realize it, muscular activity generates a great deal of heat. It is this same heat that allows us to maintain a constant healthy body temperature.

Muscle has one basic movement: contraction. Because muscles can only contract, an action depends on which bone a muscle is attached to, how it is attached, and the other bones and muscles involved in movement. Taking a single step, for instance, requires the participation of almost every single muscle below the shoulders—almost 200 muscles!

How does a muscle contract? Contraction is actually the result of a complex chemical reaction. When the brain wants the body to move, it releases a chemical signal called **acetylcholine**. When the acetylcholine reaches the muscle fibers, it creates an electrical impulse. This impulse causes microscopic structures within the muscle to flex, or contract. As thousands of fibers contract, it produces movement in the muscle. This movement "shortens" the muscle as the two ends are pulled towards one another, in turn moving the bone to which the muscle is attached. This process—from the time that the signal leaves the brain to the time that the muscle contracts—takes only milliseconds.

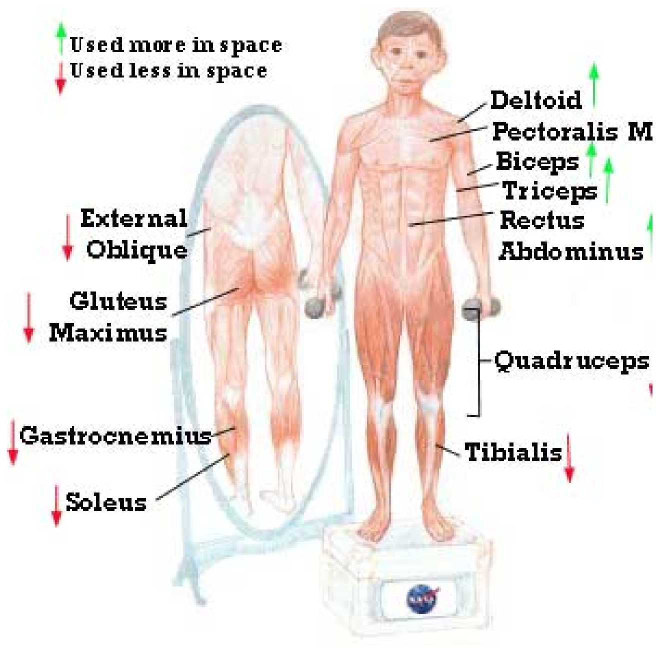
Muscles work in **antagonistic pairs**. The contraction of one of the muscles in the pair allows the relaxation of the other. Let's examine the upper arm as an example. Imagine, for example, that you are lifting weights. When you bend your elbow and bring your hand to your shoulder you are contracting your biceps. While the bicep is contracted, the tricep is relaxed. In order to bring your arm back down, the triceps contracts, allowing the bicep to relax.

When a person is conscious, all of their muscles are slightly contracted. This normal condition is called **tonus**. Tonus helps maintain our upright posture by partially contracting the back, neck, and leg muscles. Tonus also stimulates muscle, keeping it firm, healthy, and ready for use. If muscles are not stimulated, they lose tone and begin to waste away, or **atrophy**. As we are about to see, this lack of stimulation leads to problems for astronauts on extended space missions.

Muscle in Space

You may recall from our discussion of bones that astronauts on orbit do not move around in the same way they do on Earth. On Earth, moving from place to place is generally accomplished by walking. When we stay still, we either sit or stand. All of these motions keep our muscles constantly flexing and relaxing, especially the muscles in our legs and back that keep the body upright against gravity. In space, however, many of these muscles go unused. An astronaut can float effortlessly in one position when working on a task; the leg muscles are not needed to keep the astronaut upright. Similarly, to move from one end of the spacecraft to the other, an astronaut can pull him- or herself forward by the arms. Again, there is no need to use the legs.

Muscles are used differently in space than they are on Earth



Adapted from NSBRI *Human Physiology in Space*

Like bone, muscle must be constantly stimulated in order to maintain strength. This is not a problem on Earth, but in space the new ways of moving leads to muscle **atrophy**. In other words, an astronaut's unused muscles become smaller and weaker. Astronauts may lose strength, size, and control in their muscles. Scientists think that the body's normal process of protein metabolism that maintains muscular structure and strength on Earth is adversely affected by microgravity.

Muscle atrophy does not necessarily present a problem while the astronaut is still in space. However, astronauts returning from long-duration stays in space are often weak upon return to Earth. Although their lost muscle is eventually rebuilt, scientists are still looking for ways to prevent muscle atrophy.

A proper diet is one way that astronauts can maintain their muscle strength while they are in space. Exercise is also very important. There are two types of exercise that are essential to maintaining muscle tone: endurance exercise and resistance exercise. Endurance, or aerobic, exercise results in strong muscles that are more resistant to fatigue. Astronauts may use treadmills or stationary exercise bikes to perform endurance exercises in microgravity. Resistance exercise, like weightlifting and other isometric activities, maintains and improves muscle tone. Future methods of muscle maintenance may involve new types of exercise and exercise equipment, vitamins, hormone supplements, or maybe even artificial gravity.

Muscle atrophy is not solely limited to astronauts on long missions. Many Earth-bound patients recovering from injury or illness also experience muscle atrophy. This leads to a prolonged recovery, since not only must they overcome their medical challenge, but they must also rebuild the muscle they have lost. For instance, the muscles of a broken leg will atrophy as the leg is held immobile and unused as it heals. The patient must then undergo several weeks (or longer) of rehabilitative therapy before they are walking normally again. As NASA scientists work to understand atrophy in astronauts, we will also learn to limit, or even completely prevent, muscle atrophy in people on Earth.

Activity #2: Models with Muscle

Adapted with kind permission from an activity presented at
International Space Station Educator's Conference 2000 by
John Vose, Miki Branch, Heather Smith,
C.R. Clements Intermediate School,
Copperas Cove, Texas

Objectives

Following this activity, the student will

- Understand the concept of antagonistic muscle groups
- Understand the interaction between muscles and joints

National Science Education Standards

Unifying Concepts & Processes in Science
  - Evidence, models, and explanation
  - Form and function

Science as Inquiry
  - Abilities necessary to do scientific inquiry
  - Understanding about scientific inquiry

Life Science
  - Structure and function in living systems

Science in Perspective
  - Personal health

Materials Needed

Each student will need:

- Activity guide
- A piece of foam board large enough to trace their hand onto
- 3 or 4 plastic drinking straws
- 3 meters of string
- One hot-glue gun for every four students (regular glue may be used but takes much longer to dry)
- Sharp craft knife
- Scissors

Activity

1. Allow at least two hours for this activity. Post the safety rules in a highly visible location.
2. Begin with a refresher discussion of muscles and bones. Specifically, remind students that to create movement, muscles operate an important system of levers—our bones. The fulcrums of these levers are **joints**, the places where bones meet.

3. Using a demonstration model, show how the straws act as joints, and the strings act as muscle.
4. Students should follow the directions on Student Worksheet #1. Stress safety (knives and glue guns) before and during the activity.

Discussion

Following the activity, bring the students back together for a group discussion. Ask students how they think this relates to real muscles. Students should understand that the only way to relax the contracted fist muscles was to engage an opposite set of muscles. In other words, muscles can only contract, and it requires the contraction of another set of muscles to help them relax. This is why muscles work in antagonistic pairs.

Assessment

Student worksheets may be used as assessment.

Extensions

- Allow students to create another hand, with variations in straw placement. How does this affect the working of the hand? Can they think of specific placements that will allow them to do different things?
- Have students design and create a model of the leg and its major muscle groups. Along with their hand models, students should demonstrate the differences between movement in space and movement on Earth. Which groups of muscle are not used? Which are used more? What are the consequences of these changes?
- Use these models to initiate a discussion about robotic manipulators. Have students compare this model to machines. Their hand models don't work perfectly, which is one example of why it's hard to mimic the human body's actions in robots. This may expand into a discussion of what robotic manipulators are used for and their limitations. Students may design and create their own manipulators, or try to think of ways they would improve existing manipulators.

Models with Muscle

Watching your hand very carefully, perform the following series of actions:

Hold your pen. Drop it on the desk. Now pick it back up.

What happened? Was it one muscular movement, or did it require the efforts of many muscles working together? Did your muscles all move in one direction, or did they do many things? In this activity, we will look at these questions.

Get Ready

You will need:

- Piece of foam board large enough to trace your hand onto
- Plastic drinking straws (three or four)
- String (about 3 meters)
- A hot glue gun and glue sticks
- Craft knife
- Scissors

Think about it

1. When you grasped your pen, was that a single muscle working or was it many muscles working together?

2. Do muscles “pull” or “push” on bones?

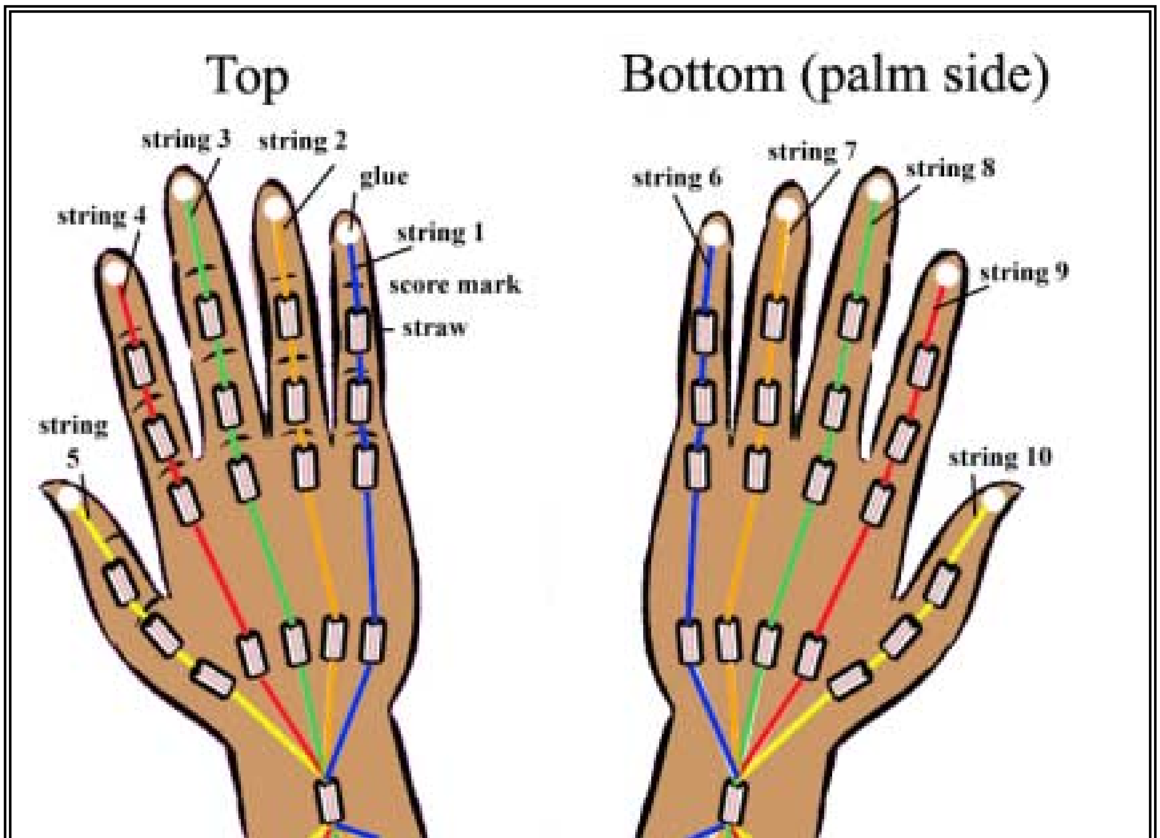
Formulate your hypothesis

What will happen if a muscle can only contract?

Test your hypothesis

To test your hypothesis, you will need to construct a model of your hand that will allow you to watch how the muscles work. Below is a diagram that you may follow to construct your hand.

1. Trace an outline of your hand onto the foam board.
2. Cut out the hand using a sharp knife, remembering the safety tips *at all times*.
3. Compare your hand to the outline you've drawn. Mark the locations of all joints (knuckles) on the foam board hand. The side you mark will become the top (back side) of your hand. The unmarked side becomes the bottom (palm side) of your hand.
4. **Score** the foam board at each joint. This means that you should only cut through the foam board about halfway, not all the way through. This allows the foam board to bend back and forth.
5. Cut the straws into short pieces using scissors. The straw pieces should be small enough to fit in between the score marks.
6. Use your glue gun to glue the straw pieces onto your foam hand according to the diagram.
7. Cut the string into ten pieces, each 30 centimeters long.
8. Run a string from each fingertip, through the straws of that finger, and to the wrist. Thread all the strings through the bottom-most straw of the wrist. Do this on both sides of the hand. These strings will act like your hand **muscles**.
9. Hot glue the end of each string to the fingertip.



Make observations

Now go ahead and test out your new hand. First examine what happens when you make a fist. To do this, pull on all of the strings (at the same time) that attach to the bottom (palm side) of your hand. What happens?

Now it's time to unclench your fist. How will you accomplish this?

Apply this to your own hand and your own muscles. In order to make the fist, what would your muscles have to do? To unclench your fist, what would have to happen? What happens if you pull different strings at different times?

Safety Tips

1. Use the knife only while seated.

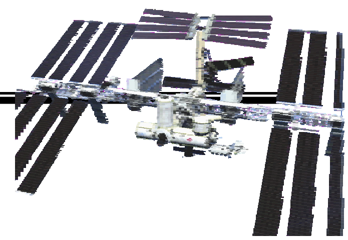
2. Cover the tip of your knife *any time you are not using it.* Cover it even if you have stopped using it for only a few seconds.

3. Keep your eyes on the knife whenever you are using it.

4. Keep your body out of the line of your cut. Always move the knife *away* from you. Avoid putting parts of your body behind or under the material being cut.

5. Use a minimum of force. Do not force the knife to do more than it can—this may make the knife slip and you may injure yourself. If one cut is not enough to cut all the way through the foam board, go back and cut in the same place more than once.

The Cardiopulmonary System



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A Virtual Astronaut Teacher's Guide

Introduction

You may think of the system that moves blood throughout your body (**circulatory system**, also called the **cardiovascular system**) as completely separate from the system that is responsible for your breathing (the **respiratory system**). This is not entirely true. Without the circulatory system to transport oxygen to your cells, the respiratory system could not function. Together, the circulatory and respiratory systems make up the cardiopulmonary system—the system responsible for transporting blood, nutrients, gases, and wastes throughout the entire body.

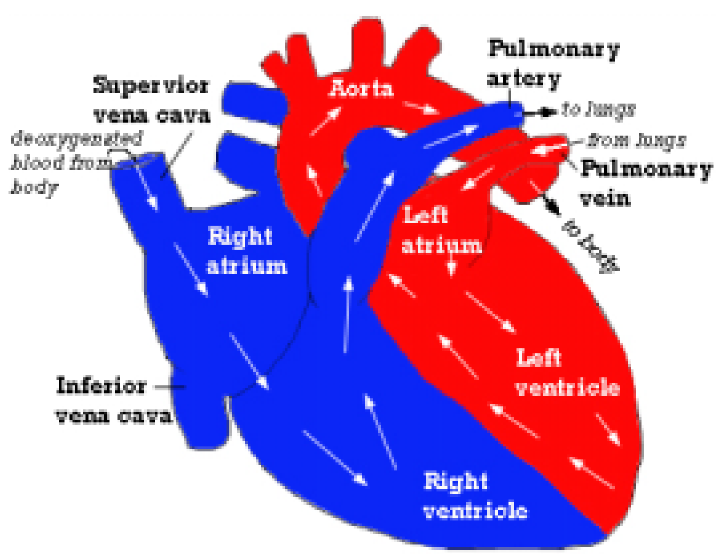
Just like the skeletal and muscular systems, the cardiopulmonary system has developed partially in response to the gravitational forces found on Earth. When an astronaut reaches orbit and the forces of gravity dwindle to almost nothing, the cardiovascular system changes in response.

Before we examine how the cardiopulmonary system changes in space, we first need to understand a few things about the circulatory and respiratory systems on Earth.

The Circulatory System on Earth

The main job of the circulatory system is to keep blood circulating throughout the entire body. This requires many parts of the body to work together: the heart, arteries, veins, and capillaries. The heart pumps blood from head to toe, while the arteries and veins transport oxygen, carbon dioxide, nutrients, and wastes to and from the appropriate cells and organs.

Flow of Blood Through the Heart



Let's take a simplified trip through the circulatory system, starting at the heart. The heart is divided into four chambers: the left ventricle, the left atrium, the right ventricle, and the right atrium. Each chamber has a different function. **Deoxygenated** blood (blood in which the **red blood cells** are not carrying any oxygen) enters the heart at the top, through vessels called the **superior** and **inferior vena cava**, and moves into the right atrium. The atrium contracts and squeezes the deoxygenated blood into the right ventricle. The right ventricle then contracts, sending blood towards the lungs through the pulmonary arteries. At the lungs, the blood moves into the pulmonary capillaries. On its way through these lung blood vessels, the **hemoglobin** in the red blood cells "soaks up" the oxygen that has been inhaled (we will discuss the breathing process in the next section). The **oxygenated** blood cells then leave the lungs and enter the pulmonary vein. The pulmonary vein returns the oxygenated blood to the heart, where it enters the left atrium. As the left atrium contracts, it forces blood into the left ventricle. Contraction in the left ventricle then pushes blood into the aorta, from where the oxygenated blood is distributed throughout the body. This blood then distributes the oxygen to the body's organs and cells. As the body's cells take up the oxygen from the blood, the blood again becomes deoxygenated, and returns to the heart to repeat the cycle. This entire sequence—from heart to lungs to heart to body and back again—only takes approximately 20 seconds.

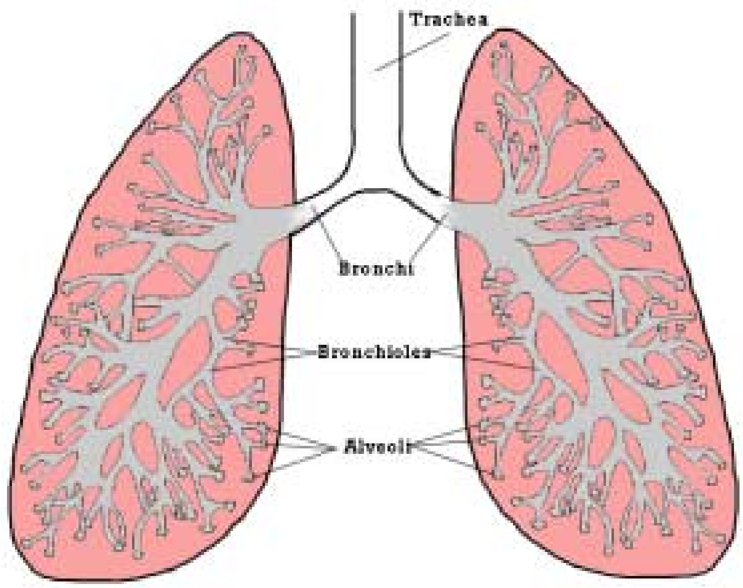
How is blood *kept* circulating? The contraction of the heart sends out new impulses of movement with every heartbeat, which push the blood throughout the body. More specifically, the **blood pressure** (the force exerted by the blood against the walls of the blood vessels) created by this pumping keeps blood circulating throughout the body. And, although you may not realize it, gravity also affects blood circulation. The pull of gravity helps the blood reach the lower extremities. When a person is standing up, for example, gravity pulls blood down into the legs. Since the body must work a little bit harder in order to push blood up towards the head, against the flow of gravity, our leg muscles also work as a kind of pump to push blood upwards. As we move our legs—walking and running, for instance—the contraction of the leg muscles forces blood back up the leg veins, towards the heart. The specific construction of veins does not allow blood to flow back down.

The Respiratory System on Earth

We have now seen how the circulatory system brings oxygen from the lungs to the rest of the body. How did the oxygen get to the lungs in the first place? The answer lies with the respiratory system. The respiratory system is responsible for bringing oxygen into the body and expelling carbon dioxide, the waste product from some cellular activity. This is done in a three-stage process: breathing, which moves air in and out of the lungs; gas exchange between the lungs and the blood; and gas exchange between the blood and the body's cells.

As we inhale, air is drawn into the lungs through the nose and mouth. Air travels down the **trachea**, or windpipe, and into two large tubes called **bronchi.** Each bronchi delivers air into each lung. The bronchi branch into smaller tubes, called **bronchioles**, which direct the air into thin-walled sacs called **alveoli**. The alveoli are covered in the pulmonary capillaries that allow

Parts of the Lung



passing red blood cells to travel through and take up oxygen from the inhaled air.

Similar events allow the body to rid itself of carbon dioxide. Deoxygenated red blood cells pick up carbon dioxide from the body's cells and carry it back to the lungs, where the alveoli retrieve the carbon dioxide from the red blood cells. Carbon dioxide is then sent back through the bronchioles, into the bronchi, up the windpipe, and out through the nose and mouth during exhalation.

The Cardiopulmonary System in Space

We have seen that one of the main effects of gravity on the cardiopulmonary system is directional—it pulls blood and fluid down towards the legs and feet. What happens in space when the force of gravity is no longer a factor?

The cardiopulmonary system's reaction to microgravity begins quickly. The heart becomes **deconditioned**—it no longer has to pump as hard in order for blood to overcome gravity and reach the head. There is also an outwards sign of changes in the cardiopulmonary system. Because gravity is no longer pulling it "down" towards the legs, blood and other fluids pool in the upper body. This creates "puffy face syndrome," in which the additional fluids in an astronaut's upper body make their face look swollen.

As more and more fluid moves towards the head, the heart enlarges in order to accommodate the increased volume of blood in the upper body. This tricks the brain and other systems into thinking that there is an extreme excess of blood and fluids (even though it is the distribution, not the volume, that has changed). To correct this, the body tries to get rid of the “extra” fluid. The kidneys produce greater amounts of urine. At the same time, an astronaut will be less thirsty than on Earth and drink less. These two reactions lead to a decrease in blood volume. Once this happens, the heart shrinks back to a smaller size.

This is not necessarily a dangerous condition as long as the astronaut remains in space. Once the astronaut returns to Earth, however, there can be serious consequences. The heart must recondition itself to pump blood harder in order to overcome gravity, creating a potentially dangerous blood pressure situation. Gravity again begins to pull blood and fluids downwards, but because the body has rid itself of so much fluid in space, there is no longer enough fluid to function normally on Earth. Although the cardiopulmonary system will gradually readapt, astronauts risk low blood pressure, a feeling of faintness, and reduced physical stamina during and after landing—a time at which they need to be in peak condition to respond to any emergency.

NASA scientists are researching ways to limit changes in astronauts’ cardiac function. Past methods include exercise, ingestion of salt water to build up fluid levels, and the wearing of “g-suits” during landing, which prevent blood from pooling in the legs. New avenues of investigation involve neurochemistry, pharmacology, and even feedback training, which allows astronauts to voluntarily control involuntary muscle action. As scientists begin to better understand the cardiopulmonary system in space, we will apply what we have learned to improve the heart health of people on Earth.

Activity #3: May the Force Be With You

Adapted from an activity created by Berni Schuhmann
for the NASA-Ames STELLAR Program
Complete activity can be found at
http://weboflife.arc.nasa.gov/stellar/Activities/cardiovascular/May%20the%20Force/MayTheForce.html

Objective

The student will be able to

- Identify the changes to the cardiovascular system caused by microgravity (µg)
- Explain centripetal force and how it may be used as a countermeasure during space flight

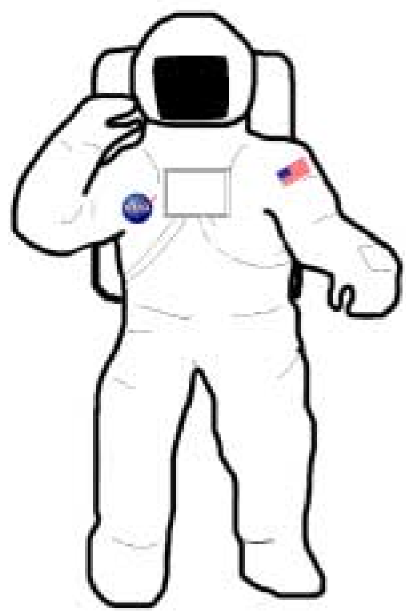
National Science Standards

Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Life Science
- Structure and function in living systems

Science in Personal and Social Perspective
- Personal health

History and Nature of Science
- Nature of science



Materials Needed

- One activity sheet per student
- Experimental Design sheets for each station
- One stopwatch or other timer for each station (electric centrifuges only)

For model astronauts:
- 4 small water bottles
- 2 cups of water
- 4 tablespoons salt
- red food coloring
- 4 paint sticks
- 4 foam wedges
- clear packing tape

For centrifuges:
- foam board, 2 pieces at least 40-cm. wide
- scissors
- circle compass
- masking tape

- 2 record players (**Note**: If record players are not available, there are directions for creating turntables in the procedure section)
- 2 records (45 rpm)
- 2 spools from gift wrap ribbon

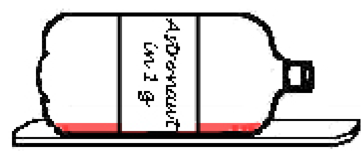
Assembly Procedure

Note: You may consider having students construct the centrifuges. Allow one extra class period for student construction.

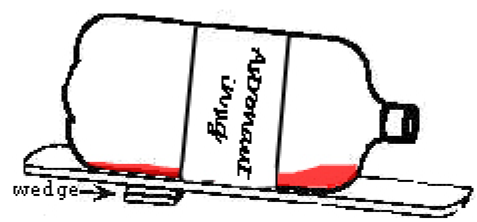
To construct model astronauts:

1. First mix the “blood” solution: add 4 tablespoons of salt to 2 cups of water. Add enough food coloring to turn the water red.
2. Put ½ cup of water into each water bottle. Replace the tops and tape them shut.
3. Tape labels that read “Astronaut in 1g”on two of the bottles. On the other two bottles, tape labes that read “Astronaut in µg.” These bottles represent astronauts in Earth’s gravity and in space, respectively. The top of the bottle represents the astronaut’s head, and the bottom of the bottle represents the astronaut’s feet.
4. Tape each bottle to a paint stick.
5. Attach a small foam wedge under the stick near the bottoms of the “Astronaut in µg” bottles. This will tilt the bottle so that the liquid is distributed unevenly, with more in the “head” of the astronaut than in the “feet.”

Astronaut in 1g bottle



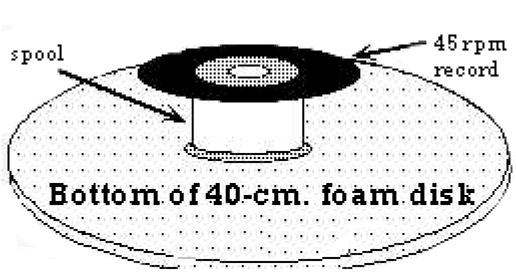
Astronaut in µg bottle



To construct record player centrifuges:

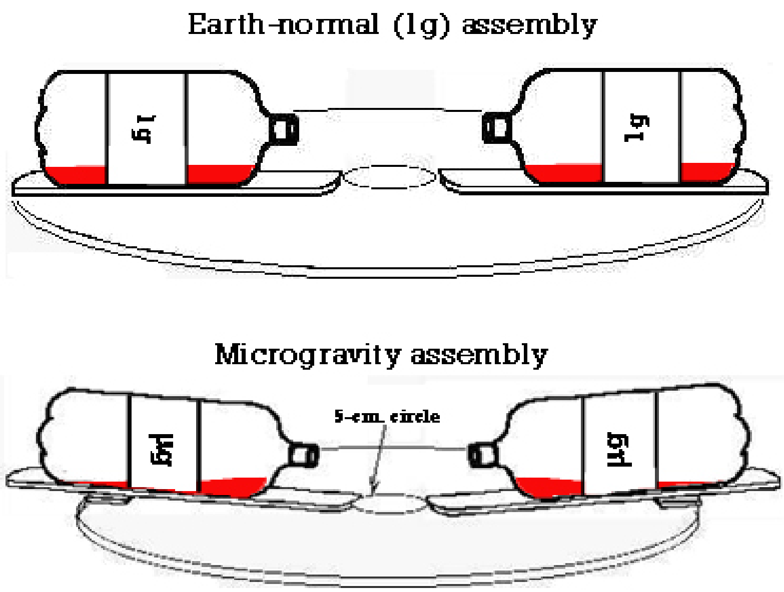
1. Cut a 40-cm. disk from the foam board.
2. Using a compass, draw a 5-cm. circle in the center of the disk.
3. Glue a 45-rpm. record the the bottom of an empty ribbon spool.
4. Glue the other end of the ribbon spool to the bottom of the disk. Make sure both the record and the disk are centered on the spool.
5. Tape two Astronaut Models (both 1g or both µg) onto the top of the 40-cm. disk, with the paint sticks just touching the mark of the 5-cm. circle, and with the caps of the bottles pointed toward the center.
6. Place the centrifuge assembly on the record player. You may wish to

Record player centrifuge
(steps 1-4)



make two assemblies—one for the Earth gravity astronauts, and one for the microgravity astronauts.

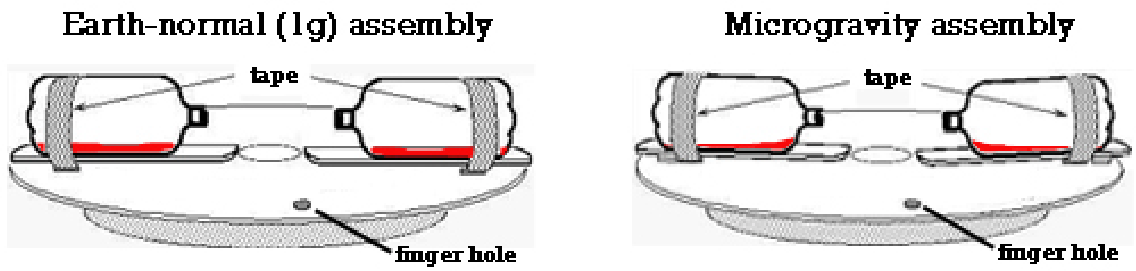
Completed Record Player Centrifuges



To construct a lazy susan centrifuge (hand spun)

1. Cut a 40-cm. disk from the foamboard.
2. Cut a “finger-hole” in the 40-cm. disk to facilitate rotating the disk. Put your finger through the finger-hole and move your hand in a circular fashion to spin the disk.
3. Using a compass, make a circle 10-cm. from the center of the disk.
4. Tape two Astronaut Models (either both 1g or both µg) onto the top of the 40-cm. disk, with the paint sticks just touching the mark of the 5 cm. circle, and with the caps of the bottles pointed toward the center. Make sure the bottles are lined up.
5. Cut four holes or slots in the disk, one on each side of each astronaut/bottle and pass tape through the holes and around each bottle, to secure the bottles on the disk.
6. Tape or glue the disk to the top of a lazy susan. Make sure it is centered.
7. Place the lazy susan on its base.

Completed Lazy Susan Centrifuges



To set up the classroom:

1. Create "stations" for students to work at. One station should hold the Earth-normal assembly, and one should hold the microgravity assembly. P
2. Place Experimental Design sheets and timers at the appropriate station. Students may begin at either station.
3. You may wish to create several types of each assembly to allow more students to work at once, or allow students to work in groups.
4. Make enough copies of the appropriate data collection sheets for each student.

Investigation Procedure

1. Before beginning the activity, initiate a discussion of the effects of microgravity on the human body. Direct the discussion so that it winds up with an emphasis on fluid shift.
2. Discuss the idea of microgravity simulation. Explain that we can simulate the physiologial effects of microgravity to some extent by laying down with our feet above our heads. This causes the blood to pool in our heads and upper bodies—the same thing that happens to astronauts during spaceflight.
3. Discuss centripital force. Explain how it can redistribute fluids and create a simulated gravitational force.
4. Direct your student's attention to the Earth-gravity and microgravity stations. Explain that they are going to investigate the effects of microgravity on a human body. Show how the bottles represent the distribution of blood: on Earth and in the Earth bottle, the blood is distributed evenly, while in space and in the microgravity bottle, blood pools towards the top.
5. Students should follow directions on their student worksheets.
6. Following the activity, have students gather back together. Discuss class results. How did they differ? What may have caused the differences?

Extensions

1. Circulatory System Relay
   http://weboflife.arc.nasa.gov/stellar/Activities/cardiovascular/CirculRelay/CirculRelay.html
2. Heads Up Heads Down
   http://weboflife.arc.nasa.gov/stellar/Activities/cardiovascular/Heads%20Up%20Heads%20Down/HeadsUp.html
3. Why Giraffes Don’t Faint
   http://weboflife.arc.nasa.gov/stellar/Activities/cardiovascular/Why%20Giraffes%20Don%27t%20Faint/Giraffes.html

Assessment

Student worksheets may be used for assessment.

Experiment Design:
Electric Centrifuge
Earth-normal gravity

1. Record each observation on your Earth-normal worksheet.
2. Observe blood level in Earth-normal gravity (at rest).
3. Set record player speed to 16 rpm and observe blood distribution for at least 15 seconds. Record the blood distribution on your worksheet.
4. Switch speed to 33 rpm and observe blood distribution or at least 15 seconds. Record the blood distribution on your worksheet.
5. Switch speed to 45 rpm and observe blood distribution or at least 15 seconds. Record the blood distribution on your worksheet.
6. Switch speed to 72 rpm and observe blood distribution for at least 15 seconds. Record the blood distribution on your worksheet.
7. Reduce speed to 45 rpm and observe blood distribution for at least 15 seconds. Record the blood distribution on your worksheet.
8. Reduce speed to 33 rpm and observe blood distribution for at least 15 seconds. Record the blood distribution on your worksheet.
9. Stop the record player.
10. How long does it take for the blood to return to a normal (at rest) distribution?

Experiment Design:
Electric Centrifuge
Microgravity

Record each observation on your Microgravity worksheet.

1. Observe blood level in Earth-normal gravity (at rest).

2. Set record player speed to 16 rpm and observe blood distribution for at least 15 seconds. Record the blood distribution on your worksheet.

3. Switch speed to 33 rpm and observe blood distribution for at least 15 seconds. Record the blood distribution on your worksheet.

4. Switch speed to 45 rpm and observe blood distribution or at least 15 seconds. Record the blood distribution on your worksheet.

5. Switch speed to 72 rpm and observe blood distribution for at least 15 seconds. Record the blood distribution on your worksheet.

6. Reduce speed to 45 rpm and observe blood distribution for at least 15 seconds. Record the blood distribution on your worksheet.

7. Reduce speed to 33 rpm and observe blood distribution for at least 15 seconds. Record the blood distribution on your worksheet.

8. Stop the record player.

9. How long does it take for the blood to return to a normal (at rest) distribution?

Experiment Design:
Hand-Spun Centrifuge
Earth-normal gravity

Record your observations on your Earth-normal worksheet.

1. Observe blood distribution of Earth-normal gravity (at rest).

2. Spin the centrifuge 10 times. Observe and record the blood distribution on your worksheet.

3. Spin the centrifuge 10 more times. Observe and record the blood distribution on your worksheet.

4. Observe the blood distribution as your centrifuge slows down. Count how many spins it takes for the blood to return to Earth-normal (at rest) distribution.

Experiment Design:
Hand-Spun Centrifuge
Microgravity

Record your observations on your Earth-normal worksheet.

1. Observe blood level of microgravity (at rest).

2. Spin the centrifuge 10 times. Observe and record the blood distribution on your worksheet.

3. Spin the centrifuge 10 more times. Observe and record the blood distribution on your worksheet.

4. Observe the distribution of blood as the centrifuge slows down. Count the numer of spins it takes before the blood returns to normal (at-rest) microgravity distribution.

May the Force Be With You

Have you ever thought about the shape of your face? Is it round, oval, rectangular, narrow? Does the shape of your face ever change?

Before (left) and after (right): fluid shifts caused by microgravity can change the shape of an astronaut's face

Of course, everyone's face changes as they grow. It may even change after reaching adulthood, especially if you gain or lose weight. When astronauts travel into space, however, their faces change even more. In fact, their faces become so round and puffy that this condition is called "puffy face syndrome." Why does this happen?

Puffy face syndrome is one result of the changes that *microgravity* brings to the human body. In this experiment, we will investigate the possible causes of puffy face syndrome, and possibly even come up with some ways to combat it.

Think about it

1. Why is your face shaped the way it is?

2. What changes when an astronaut goes in to space? (Hint: think about the direction in which gravity pulls).

Formulate a hypothesis

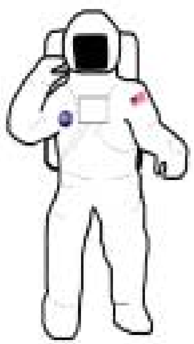
How will the force of gravity affect the distribution of fluids in the body?

To test your hypothesis, proceed to one of the two Centrifuge Stations and follow the directions you find there. It does not matter where you start. Record your observations on your Data Collection sheet.

Electric Centrifuge
Data Collection

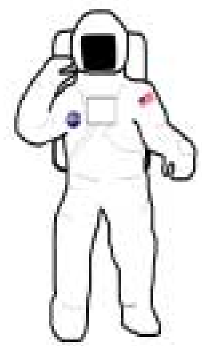
Using what you see occurring in the water bottle, *extrapolate* to a human model. The end of the bottle with the cap represents the astronaut's head, and the base of the bottle represents the astronaut's feet.

EARTH NORMAL GRAVITY OBSERVATIONS
Record the distribution of blood in the astronaut's body at the following speeds:


AT REST

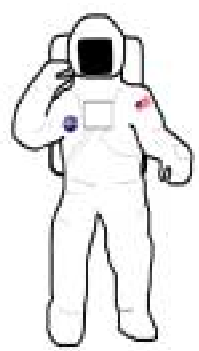

16 RPM

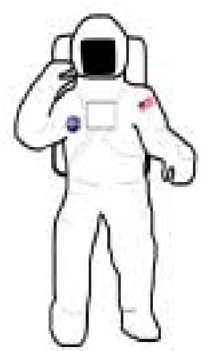

32 RPM


45 RPM


72 RPM


45 RPM


33 RPM


16 RPM

How long did it take for the blood distribution to return to normal?

At what speed did you see the effects of *hypergravity* (blood distributed to the feet of the astronaut)?

Electric Centrifuge
Data Collection
Pg. 2

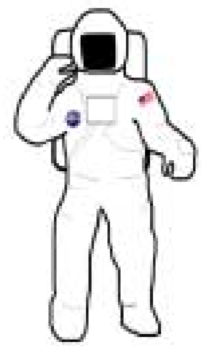
MICROGRAVITY OBSERVATIONS

Record the distribution of blood in the astronaut's body at the following speeds:

AT REST

16 RPM

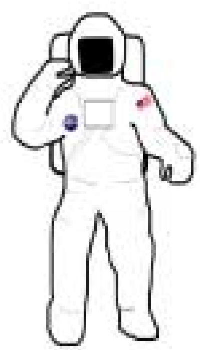
33 RPM



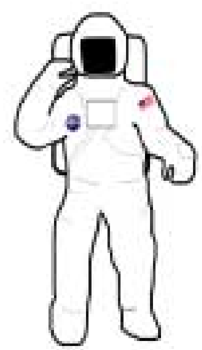
45 RPM

72 RPM

45 RPM



33 RPM



At rest

Which speed is best for obtaining Earth-normal distribution?

How long did it take for the blood distribution to return to normal?

Electric Centrifuge
Data Collection
Pg. 3

Analyze the results

1. Which rpm speed works best to provide “Earth-normal” blood levels in microgravity?

2. What happens when Earth-normal astronauts are spun on a centrifuge?

3. At what rpm does blood pool in the “feet” in Earth-normal astronauts?

4. How long did it take for the hypergravity created in Earth-normal models to return to normal after spinning?

5. What have you learned about centripetal force?

6. How did the force of gravity affect the astronauts (think back to your hypothesis!)?

7. Can you think of a way that we may prevent “puffy face” syndrome and other effects of microgravity on the human body?

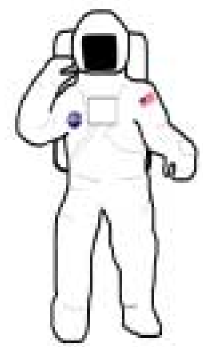
Hand-Spun Centrifuge
Data Collection

Using what you see occurring in the water bottle, *extrapolate* to a human model. The end of the bottle with the cap represents the astronaut's head, and the base of the bottle represents the astronaut's feet.

EARTH NORMAL GRAVITY OBSERVATIONS
Record the distribution of blood in the astronaut's body at the following speeds:

At rest

10 spins



20 spins

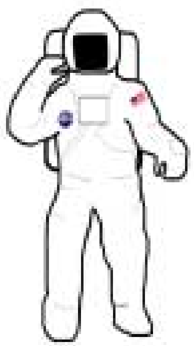
How long did it take for the blood distribution to return to normal?

How many spins did it take to get the blood to *hypergravity* (blood distributed to the feet of the astronaut)?

Hand-Spun Centrifuge
Data Collection
Pg. 2

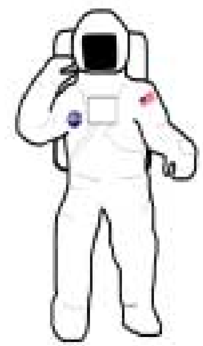
MICROGRAVITY OBSERVATIONS

Record the distribution of blood in the astronaut's body at the following speeds:



At rest

10 spins



20 spins

How many spins did it take to get the blood distribution to Earth-normal gravity?

Which speed is best for obtaining Earth-normal distribution?

Hand-Spun Centrifuge
Data Collection
Pg. 3

Analyze the results

1. How many turns of the centrifuge did it take to create an Earth-normal blood distribution in the astronauts?

2. What happens when Earth-normal astronauts are spun on a centrifuge?

3. How many turns did it take before blood pooled in the "feet" in Earth-normal astronauts?

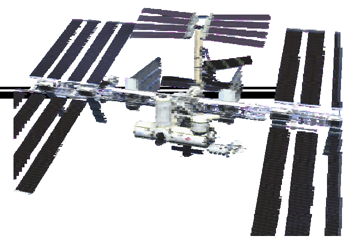
4. How long did it take for the hypergravity created in Earth-normal models to return to normal after spinning?

5. What have you learned about centripetal force?

6. How did the force of gravity affect the astronauts (think back to your hypothesis!)?

7. Can you think of a way that we may prevent "puffy face" syndrome and other effects of microgravity on the human body?

The Immune System



Inner Space in Outer Space:
A Virtual Astronaut Teacher's Guide

Introduction

Until now we have looked at microgravity's effects on **organ systems**—specific structures that work to perform a vital body function. Now let's look at microgravity's effects on a **functional system**: the immune system.

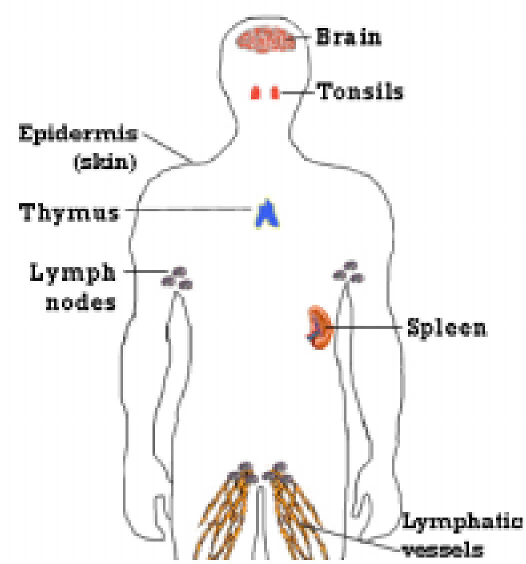
Our immune system protects us from harmful bacteria and viruses, and sometimes even our own cells. Some of the "structures" of the immune system are actually a variety of special molecules and cells circulating throughout the body. Without these structures, or when these structures are "overpowered" by invading organisms, our bodies cannot effectively fight disease, and we become sick.

The immune system is identical to the organ systems we have discussed in at least one important way: the immune system is equally affected by space flight. Let's take a look at how the immune system keeps us healthy on Earth, and what happens to the immune system in space.

The Immune System on Earth

The human body must be able to defend itself against **pathogens** (disease-causing microorganisms) or other foreign cells that have entered our body. Our immune system relies on a number of different structures and organs to fight off infection and keep it from recurring. Our **tonsils** trap and remove pathogens before they can enter the throat. **Lymph nodes** remove pathogens from the body and, as we will see, produce key cells that function in the immune response. **Lymphatic vessels**, also part of the circulatory system, transport pathogens to the lymph nodes and carry disease-fighting cells to and from the site of infection. The **spleen** not only produces **lymphocytes** (white blood cells that fight disease), but also cleans and filters blood. The **thymus**, which is most active during childhood, produces critical hormones that "tell" lymphocytes what to do. In addition, neurotransmitters produced in the brain and hormones produced by endocrine glands enhance our ability to resist or recover from disease.

The immune system involves a number of structures



Although our immune system is quite good at keeping us healthy, there is one major drawback: the body must be exposed to a pathogen before it can mount a defense against that pathogen. To overcome this potential problem, the human body has evolved with two types of immunity that work together to protect against pathogens and foreign bodies: **non-specific defenses** and **specific defenses**.

<u>Non-specific defenses</u>

Non-specific defenses are the physical barriers that the body presents against the environment, as well as the cells and chemicals that lead the initial attack against invading cells. The first line of defense is the body's non-specific surface membrane barriers—in other words, the skin and the mucous membranes. As long as the skin remains unbroken, the keratin in the **epidermis** (the outermost layer of skin) provides a physical barrier to pathogens. If the pathogen can't get past the skin, it can't infect the body. Additionally, skin secretions are actually acidic. Bacteria cannot grow in this acidic environment and, if that weren't enough, the **sebum** secreted by small glands just under the skin contains chemicals that kill bacteria.

Mucous membranes act as physical barrier to prevent pathogens from entering the human body. These membranes line all body cavities with an opening to the external environment, including the digestive, respiratory, urinary, and reproductive tracts. Mucous membranes also produce a variety of protective chemicals. The mucus secreted by mucous membranes, for instance, traps microorganisms and prevents them from entering the body. The gastric juice produced by the stomach's membrane contains strong acid and digestive enzymes that "eat" the pathogens before they can be passed from the digestive system into the body. Some mucous membranes, like the nasal passage, contain small hairs that filter and trap microorganisms before they can enter the body. These hairs, or **cilia**, actually sweep dust and bacteria up and away from the lungs. Even tears and saliva are protective devices: they keep the eyes and mouth clean and also contain **lysozyme**, an enzyme that destroys microorganisms.

Several types of special cells and chemicals play an important part in secondary nonspecific defense. **Phagocytes** surround and "eat" foreign cells. **Complement proteins** are a group of blood plasma proteins that circulate throughout the body. These proteins are inactive until they become attached to a foreign cell. When this happens, in a process called **complement fixation**, the actions of the proteins cause the foreign cell to rupture and burst. **Interferons** are another form of non-specific defense. These molecules actually keep healthy cells safe from viruses. The interferons bind with the healthy cells, which hampers the virus's ability to take over the cell and multiply, although scientists have not yet identified the specific mechanism.

<u>Specific Defenses</u>

Despite the body's front-line non-specific defenses, sometimes pathogens continue to advance into our system, and the body initiates the **immune response**. While the non-specific defenses combated *all* foreign bodies in the same general way, the immune response targets specific **antigens**. An antigen is any cell that provokes an immune response. Sometimes this antigen is a foreign bacteria or virus. In some cases, it may be a foreign human cell—for example, a "strange" human cell that is actually part of a transplanted organ.

There are two types of specific defenses: **cell-mediated immunity** and **humoral immunity.** Both rely on critical cells called **lymphocytes**, a special type of white blood cell, and **macrophages**, a type of phagocyte. Let's examine each type separately.

Cell-mediated Immunity

Cell-mediated immunity relies on macrophages and **T cells**, a form of lymphocyte. When the body detects an antigen, a macrophage moves towards it, engulfs it, and brings it to the lymphocytes in the lymph nodes. It does not go to just *any* lymphocyte, however. There are thousands of varieties of inactive lymphocytes; only the lymphocytes that specifically fight the invading type of antigen become active.

Once activated, the lymphocyte (also called the **competent** or **sensitized** lymphocyte) grows and divides, giving rise to thousands of clones of itself. These clones then differentiate to become **killer T cells, helper T cells, suppressor T cells, or memory cells**. These cells, each of which have a particular role to play, leave the lymph nodes and rush to the site of infection. There, the killer T cells combine with the invading cells and release enzymes that destroy the antigens. The helper T cells act as directors—they circulate and "recruit" or signal other cells to help fight the antigens. This includes bringing other types of protective white blood cells to the area and enhancing the macrophages' ability to destroy the antigen. After the killer T and helper T cells have successfully fought off the infection, the suppressor T cells begin their work. Suppressor T cells actually inhibit the active immune defenses, allowing the body to return to its normal pre-infection state.

The final type of cell, the memory cells, remain in the body. If the same type of antigen invades the body again, the memory cells recognize the antigen immediately, allowing the body to respond quickly and mount a defense. This is why, for instance, chicken pox rarely affects a person twice. The immune system builds a number of memory cells that recognize the chicken pox virus, so if the antigen re-invades the body, the body's defenses destroy it before it can cause chicken pox again. Sometimes, however, the memory cells do not work. This occurs when the virus mutates or appears as a different strain—it changes just enough so that the memory cells do not recognize it.

Humoral Immunity
Like cell-mediated immunity, humoral immunity (also called **antibody-mediated immunity**) also relies on lymphocytes. The lymphocytes involved in this particular immune response are called **B cells**. There are thousands of types B cells, each activated by a specific antigen. When a B cell is activated, like a T cell, it divides and produces clones. Most of these cells grow and differentiate into cells called **plasma cells**. The remaining cells become memory cells, to help prevent a recurring infection.

In contrast to T cells, which travel to the site of infection, B cells do not leave the lymph nodes. Instead, B cells produce **antibodies**, highly specific proteins that are produced to fight the corresponding antigen. Antibodies are also called **immunoglobulins**. The antibodies leave the lymph nodes and travel to the infection site. There, they combine with the antigen and do several things. The most important activity that antibodies do is **complement** the antigen, causing the antigen to rupture and die. Antibodies may **neutralize** the antigen by binding with it and blocking the antigen from secreting any toxins that may harm to the body. Antibodies also enhance the action of white blood cells (like macrophages) that engulf and destroy the antigen.

Once the infection has been destroyed, the remaining memory cells help fight a reoccurrence, just like memory cells in a cell-mediated response. Unlike cell-mediated memory cells, however, the memory cells in a humoral response produce antibodies that respond when their specific antigen is detected.

The Immune System in Space
The effects of microgravity on the immune system are quite complex. In space, the immune system is affected by a number of **stresses**—a stimulus that disturbs the body's internal environment. We have already seen that microgravity affects the bones, muscles, and brain—and all of these responses produce additional stress on the immune response. For example, breakdown of bone and muscle in response to space flight creates irregular levels of calcium and protein in the bloodstream. This affects the neuroendocrine system (the system that produces hormones), which may in turn affect the immune system.

The spacecraft environment presents new stresses to the body, both physical and psychological. A spacecraft is a small, **closed** environment that creates a number of stresses. These stresses may affect any number of systems in the body that ultimately affect the immune system. There are the "daily hassles" of living in a small space habitat: individual responses to temperature, humidity, noise, vibration, light, and smells. There are a number of people living in a relatively small space; astronauts may not have the privacy and personal space they are used to. In addition, astronauts often suffer from dry skin in the dry spacecraft environment. As many Earth-bound people have learned during harsh winters, dry skin often cracks and breaks, leaving areas where pathogens may enter.

Tricks we use on Earth to stay healthy that will not necessarily work in space. We know that if we are feeling like we are getting sick, the best thing to do is get a lot of rest. Scientists have found, however, that space flight causes changes in sleep patterns, and astronauts often have trouble sleeping. In addition, the small living spaces may make it difficult to find a quiet space in which to take a long rest. The small space also makes it easy for astronauts to spread germs to one another. Even on Earth, we are well aware that we are more likely to catch a cold from our co-worker, family member, or anyone with whom we share space for a great deal of time.

Consequently, scientists do not have a clear understanding of exactly what happens to the immune system in space, or why. Medical experiments have shown shifts in the proportion of immune cells before and after flights. For example, some studies indicate the suppression of lymphocytes in returning astronauts. Without enough lymphocytes to keep them healthy, astronauts run a higher risk of infection and illness.

The exact reasons behind these shifts are difficult to determine due to the multiple factors that may affect the immune system. In addition, astronauts are a relatively healthy group! Selection criteria ensure that astronauts are fit and healthy when they join the corps. Combined with the fact that contact with other people is limited just before a flight (to prevent an astronaut from catching an infection), this means that there have been few opportunities to study illness in space. However, the new opportunities to study the effects of long-duration space flight on ISS astronauts, combined with constant biomedical research, will no doubt one day allow us to understand what happens to the immune system in space, and why, and let us ensure that our astronauts remain safe and healthy.

Activity #4: Mystery Pathogen

Objective

Following this activity, the student will be able to
- Identify ways that pathogens may infect the body
- Identify the ways the body may defend itself against pathogens

National Science Standards

Unifying Concepts and Processes in Science
- Systems, order, and organization
- Form and function

Life Science
- Structure and function in living systems

Science in Perspective
- Personal health

Materials Needed

Each team will need one copy of the Mystery Pathogen packet (includes the introduction/strategies and a Mystery Pathogen identity sheet).

Time Required

This activity may be completed in two class periods—allow one for pre-discussion and team work, and a second for the follow-up discussion.

Procedure

1. You may wish to begin this activity with a "refresher" course on the immune system. Alternately, the students' packets contain information that you may wish to review before starting.
2. Divide students into nine teams. After reading the clues about their mystery pathogen, each team should come up with a list of specific ways that a) the pathogen can enter the body, and b) that the body may defend the body against the pathogen. Their suggestions may take several forms. Emphasize that their ideas **do not have to be "real-life"**—in other words, students should use their imagination. They do not need to come up with the *actual* treatment for the disease. Instead, students should demonstrate that they understand that there a number of pathogen entry and body defense mechanisms, as well as medicines that may be created to fight the disease in a number of ways, based in part on the type of pathogen. If students are stuck, you may wish to guide them with several questions that will direct their thinking. These may include, but are not limited to:

   - Which system does this pathogen affect? (e.g., if this is a gastrointestinal [GI] disease, students must identify methods for a pathogen to infect the GI tract as well as GI defenses).

- Is there specific information about how this pathogen works that might help you formulate suggestions? (e.g. a pathogen secretes a toxin that blocks neurotransmitters: student suggestions for defense may include secretion of antitoxin, medication that enhances neurotransmitter secretion; student suggestions for invasion strategies may include direct entry into nerves and/or brain tissue)
- Are there specific symptoms that can be treated?

There is an example team answer sheet following the Extensions.

3. Bring the teams back together. Each team will present the details of their pathogen and their results. Other groups may contribute additional suggestions.

4. Students may also make guesses as to the identity of the Mystery Pathogen. Because students will be more familiar with some pathogens than others, this part of the activity should **not** be given extra credit or be considered in assessment.

Extensions

1. Discuss the spread of disease in a spacecraft. Considering factors like the close confines, recycled atmosphere, and need use stored food, students should design a spacecraft that will keep the possibility for the spread of disease to a minimum while maximizing living and working space and capability.
2. Students may further research and present further facts about their Mystery Pathogen. These reports may include additional facts about transmission, symptoms, and physiological effects. Students should also examine the history of scientific investigation of their pathogen, historical incidences of the disease, and any resulting sociopolitical effects. Presentations may take the form of oral reports, posters, skits, etc.

Assessment

Student worksheets and classroom discussion may be used for assessment.

Sample Answer Sheet

Mystery Pathogen #7

I am a virus that enters through the mouth. I grow and divide in the nose, throat, stomach, and intestines. I invade lymph tissue and enter the bloodstream. I also infect the nervous system by traveling along nerve fibers. This destroys nerve cells—and once a nerve cell is detroyed, it can't grow back. This is how I can cause paralysis if left untreated. At first, I cause fever, headache, stomach ache, and stiffness in the neck, back, and legs. Heat, chlorine, and ultraviolet light can kill me.

Based on the clues given, suggested questions to ask and answers for "Body Strategies" may include (but are not limited to):

- **This grows in the mouth, throat, nose, stomach, and intestines. How can you prevent this pathogen from getting in these ways?** Don't go near infected people who might cough or sneeze (prevent inhalation); nasal turbinates and nose hairs filter pathogen before it can enter the respiratory tract; mucus, cilia, and mucociliary elevator will trap pathogen and push it up and out before it can infect the body; stomach acid and bile will destroy pathogen; peristalsis will push pathogen out of body; rely on body's immune system (macrophages, B/T cells) to destroy pathogen once it enters bloodstream.
- **I also infect the nervous system by traveling along nerve fibers.** Develop medication that makes epithelial cells or nerve fibers "slippery" to the pathogen.
- **Heat, chlorine, and ultraviolet light can kill me:** apply any of these to a suspected contaminated surface to prevent the spread of the disease.
- **Other**: administer vaccine to prevent future infection.

Based on the clues given, suggested questions to ask and answers for "Pathogen Strategies" may include (but are not limited to):

- **"I am a virus that enters through the mouth." How can it enter the mouth?** Inhalation; entering through contaminated food and water; living on hands that get put in the mouth without washing.
- **"I grow and divide in the nose, throat, stomach, and intestines."** Thus, the pathogen must be able to survive the passage in the nose and attach to epithelial cells. Suggestions: small size to avoid nasal turbinates; physical structures that allow attachment (hooks, suckers, etc.); protective bubble to shield against stomach acid; use mucus as nutrient; secrete enzyme that destroys mucus or cilia.

Mystery Pathogen

We all know that bacteria and viruses—also called **pathogens**—make us sick. But *how* do they get into your body and make you sick? How does your body defend against them? In this activvty you will try to discover a Mystery Pathogen's invasion strategy, and at the same time plan your body's defense.

First, let's look at how your body helps keep you healthy and how pathogens try to avoid these defenses. After you have reviewed these strategies with your group, open your Mystery Pathogen identification card. Using the strategies below—and other strategies that you may develop—first try and determine the many different ways that your pathogen can infect the body. Once you have done that, try and come up with a number of ways your body can defend itself against the pathogen.

Your body works hard to keep you healthy in many ways.

- The lining of your eye keeps pathogens from entering the eye area.
- Your eyelashes, nose hairs, and small bones and cartilage in your nose (called *nasal turbinates*) filter pathogens before they can enter your body.
- Your skin protects you in several ways: it forms a protective barrier, secretes oil that is toxic to toxins, and it is acidic enough that most pathogens cannot grow there.
- Your saliva washes pathogens out of your mouth, and also contains enzymes that kill pathogens.
- Mucus and cilia (little hairs) in your nose and throat trap pathogens before they can entery our system. The *mucociliary elevator* helps push the pathogens up and out of your body.
- Your skin protects you in several ways: it forms a protective barrier, secretes oil that is deadly to toxins, and it is acidic enough that most pathogens cannot grow there.
- Most pathogens cannot survive the stomach acid and bile in your digestive system.
- Pathogens are constantly pushed out of your system by intestinal contractions called *peristalsis.*
- Your body's natural immune system can target foreign cells and kill them. Sometimes the immune system will use *macrophages*, which are a type of cell that eats pathogens. *T cells* are a type of white blood cell that can bind with and kill a pathogen. A*ntibodies* also do this.
- Your body has a lot of bacteria that lives there normally. This bacteria may secrete a toxin that kills pathogens, or simply use so much food and living space that the pathogens cannot survive in the same area.

If your body can't help, maybe a doctor can.

- A vaccine is an injection of a weakened or dead pathogen. The vaccine won't make you sick, but it will teach the body to recognize the specific pathogen. So, if the body becomes infected later, it knows how to fight the pathogen.
- Antibiotics can fight off bacteria by causing the pathogen to burst and die or by keeping the pathogen from growing and reproducing.
- Other medications may treat specific symptoms or stop infection mid-process.

But pathogens have their own tricky ways to make you sick!

- Pathogens can get past the skin or eye membranes through an open wound or other break.
- Pathogens can get past the skin through an insect or animal bite.
- Some pathogens can break down toxic skin oils.
- Some pathogens convert food to a sticky substance that stays on teeth, giving pathogens an anchor.
- Many pathogens are so small that they can avoid being trapped in the nose.
- Some pathogens take advantage of dehydration—without saliva there's no way to wash them out!
- Some pathogens are resistant to the killer enzymes in saliva. These pathogens may kill the enzymes, or they may form a protective bubble around themselves to keep the enzyme away.
- Some pathogens can form similar protective barriers against stomach acid and bile. Other pathogens can actually change the acidity around them, which neutralizes the acidity of the stomach or skin.
- Many pathogens are very clever at attaching themselves to cells that line the inner surfaces of nose, throat, stomach, and intestines (called *epithelial cells*). They may use little hooks or suckers or small fibers called pili. Some pathogens use a *binding* method—the molecules of the pathogen form a certain shape, like a key. The "lock" is the physical shape of the chemicals on the surface cells. If the pathogen key fits into the lock, it can bind to and infect the surface cells.
- Some pathogens can slow down or even destroy cilia.
- Some pathogens learn to live within the body's defenses. They actually live in phagocytes or epithelial cells, using the body's components to live.
- Some pathogens can secrete toxins that kill the body's cells or the body's normal bacteria.
- Many pathogens *mutate*—in other words, they change just enough that the body no longer recognizes them, and cannot put up a defense.

Mystery Pathogen #1

I am a virus that suppresses the immune system. I enter the bloodstream directly and attach to a particular type of white blood cell called a **helper T cell**. I get inside the T cell and replicate. Eventually the T cell bursts. This kills the T cell and spreads more of me into the body. As more and more T cells are killed, the body becomes more vulnerable to deadly infections.

How can I infect the body?	How can the body defend itself?

Can you guess what I am?

Mystery Pathogen #2

I am a virus that likes to live in the nose and throat—at first. Once there, I enter the bloodstream and affect other organs. Some doctors think I may also live on and spread along nerves just below the skin. In the beginning, I cause fever and tiredness. After a few days, a telltale skin rash appears. Sometimes this rash also appears on internal organs. I have a short survival time outside my host body. Once a person has fought me off, they rarely catch me again.

How can I infect the body?	How can the body defend itself?

Can you guess what I am?

Mystery Pathogen #3

I am a bacteria that lives mostly in the nose and throat, although I can affect any mucus membrane. I do not make you sick by myself—first, ***I*** have to be infected by a special virus. When this happens, I can produce a poisonous substance called a **toxin**. This toxin attaches to tissue or a mucus membrane and prevents the growth of new tissue or kills the old. I cause a sore throat, loss of appetite, and fever. Sometimes I create a layer of tissue across the throat that can suffocate a person if it is not treated in time.

How can I infect the body?	How can the body defend itself?

Can you guess what I am?

Mystery Pathogen #4

I am a bacteria that normally lives in the intestines of birds and other animals. Sometimes I can get into the human stomach and intestines. I can survive stomach acid and digestive enzymes—in fact, I need these things to become active! I invade and kill the cells lining the intestines, called **epithelium**. Once this happens, the intestines become inflammed. The person I've infected gets a fever, severe stomach cramps, and diarrhea. Some doctors think I may also produce a poisonous substance called a **toxin**.

How can I infect the body?	How can the body defend itself?

Can you guess what I am?

Mystery Pathogen #5

I am a highly contagious virus that lives in the cells lining the nose and throat (the **epithelium**). I attach to and invade these cells, and interfere with the way they work. This kills the cells. A person infected with me (which happens especially in winter) gets a headache, fever, and cough. I can also affect other animals, including pigs and birds.

How can I infect the body?	How can the body defend itself?

Can you guess what I am?

Mystery Pathogen #6

I am a virus that crosses mucus membranes and invades the **epithelial** cells that line the nose and throat. I leave these cells and enter the bloodstream, which transports me to the other tissues and organs of the body. I cause a telltale rash, high fever, cough, runny nose, and watery eyes. Direct application of heat or light makes me harmless.

How can I infect the body?	How can the body defend itself?

Can you guess what I am?

Mystery Pathogen #7

I am a virus that enters through the mouth. I grow and divide in the nose, throat, stomach, and intestines. I invade lymph tissue and enter the bloodstream. I also infect the nervous system by traveling along nerve fibers. This destroys nerve cells—and once a nerve cell is detroyed, it can't grow back. This is how I can cause paralysis if left untreated. At first, I cause fever, headache, stomach ache, and stiffness in the neck, back, and legs. Heat, chlorine, and ultraviolet light can kill me.

How can I infect the body?	How can the body defend itself?

Can you guess what I am?

Mystery Pathogen #8

I am a virus that can be found in the saliva of some raccoons, skunks, foxes, dogs, and bats. I can affect all mammals. Once I cross a person's skin, I can grow and divide in muscle tissue, or I can go directly into the nervous system. I travel along nerves, affecting nerve cells, tissues, and organs. A person infected with me may have a fever, headache, andeventually becomes confused, anxious, and delerious. If untreated, I cause brain damage and death.

How can I infect the body?	How can the body defend itself?

Can you guess what I am?

Mystery Pathogen #9

I am a bacteria found in the soil and in the intestinal tracts of animals. If I get through the skin of a person, I produce little structures called **spores** that release a poisonous **toxin**. These toxins block the brain from releasing important chemicals. Normally, these chemicals keep the muscles from unwanted movements. When I block the brain from releasing these chemicals, muscles contract uncontrollably. This leads to stiffness, muscle spasms, and sometimes "lockjaw." I cannot survive in the presence of oxygen, but my spores can survive most antiseptics and a lot of heat.

How can I infect the body?	How can the body defend itself?

Can you guess what I am?

Mystery Pathogen #1

I am a virus that suppresses the immune system. I enter the bloodstream directly and attach to a particular type of white blood cell called a **helper T cell**. I get inside the T cell and replicate. Eventually the T cell bursts. This kills the T cell and spreads more of me into the body. As more and more T cells are killed, the body becomes more vulnerable to deadly infections.

How can I infect the body?	How can the body defend itself?
Possible answers may include but are not limited to the following	
Get into the bloodstream directly through a break in the skin or conjunctiva	Protect broken skin with bandage, gloves, eye protection, or other protective devices
Invade the T cell using hooks, pili, suckers, or "lock and key" method	Protect the T cell with a thick membrane or chemical combination that "gums up" the lock
Replicate inside the T cell	Medication that suppresses replication
Respiratory/GI invasion strategies will not work—virus must be in bloodstream	
	B cells & antibodies or vaccination teaches the body to "recognize" and destroy the virus
	Natural T cell response will not work because they are the target of infection
	Boost the immune system synthetically, giving the body extra white blood cells

Real-life tidbits for teachers:

- This is the Human Immunodeficiency Virus (HIV), the virus that leads to AIDS. A diagnosis of AIDS is reached when the T cell count falls below a minimum requirement and the patient contracts a "signature" disease.
- At present there is no cure for HIV or AIDS. Current treatment for HIV includes a combination of several types of drugs. *Reverse transcriptase inhibitors* like AZT suppress HIV replication. *Protease inhibitors* suppress the production of infectious HIV particles.

Mystery Pathogen #2

I am a virus that likes to live in the nose and throat—at first. Once there, I enter the bloodstream and affect other organs. Some doctors think I may also live on and spread along nerves just below the skin. In the beginning, I cause fever and tiredness. After a few days, a telltale skin rash appears. Sometimes this rash also appears on internal organs. I have a short survival time outside my host body. Once a person has fought me off, they rarely catch me again.

How can I infect the body?	**How can the body defend itself?**
Possible answers may include but are not limited to the following	
Enter through inhalation	Nose hairs and nasal turbinates to form physical barriers and prevent inhalation
Small size allows passage past nasal turbinates	
Attach to nose/throat epithelial cells with hooks/pili/lock & key, etc.	Use mucociliary elevator to trap virus and push it up and out of body
Destroy or slow cilia	
Break down mucus or use mucus as nutrient	
Outcompete normal flora	Normal flora may change pH to kill virus, or produce toxins
Enter through swallowing	Lysozyme in saliva breaks down virus
	Body's natural defenses: alveolar macrophages kill virus
	Body's natural defenses: immune response teches body to recognize and kill virus before infection progresses
	Normal flora may produce toxins that kill virus or outcompete virus for nutrients and living space
Avoid body's natural defenses; produce "slime capsule" to protect against macrophages	
Affect nerves below skin: enter through break in skin or conjunctiva	
	Medication to supress replication
	Vaccine that allows body to recognize and destroy virus before infection progresses

Real-life tidbits for teachers:

- This is the Varicella Zoster Virus, which causes chicken pox.
- There has been an effective chicken pox vaccine since 1995. Doctors recommend that children receive their vaccination between 12 and 18 months of age.

Mystery Pathogen #3

I am a bacteria that lives mostly in the nose and throat, although I can affect any mucus membrane. I do not make you sick by myself—first, ***I*** have to be infected by a special virus. When this happens, I can produce a poisonous substance called a **toxin**. This toxin attaches to tissue or a mucus membrane and prevents the growth of new tissue or kills the old. I cause a sore throat, loss of appetite, and fever. Sometimes I create a layer of tissue across the throat that can suffocate a person if it is not treated in time.

How can I infect the body?	How can the body defend itself?
Possible answers may include but are not limited to the following	
Enter through inhalation	Nose hairs and nasal turbinates to form physical barriers and prevent inhalation
Small size allows passage past nasal turbinates	
Attach to nose/throat epithelial cells with hooks/pili/lock & key, etc.	Use mucociliary elevator to trap virus and push it up and out of body
Destroy or slow cilia	
Break down mucus or use mucus as nutrient	
Outcompete normal flora	Normal flora may change pH to kill virus, or produce toxins
Enter through swallowing	Lysozyme in saliva breaks down virus
	Body's natural defenses: alveolar macrophages kill virus
	Body's natural defenses: immune response teches body to recognize and kill virus before infection progresses
	Normal flora may produce toxins that kill virus or outcompete virus for nutrients and living space
Avoid body's natural defenses; produce "slime capsule" to protect against macrophages	
	Medication to supress replication
	Medication to kill special virus or neutralize toxin
	Vaccine that allows body to recognize and destroy virus before infection progresses
	Antibiotic to inhibit growth and replication of bacteria

Real-life tidbits for teachers:

- This is the *Cyrnebacterium diphtheriae* bacteria, which causes diphtheria.
- In the U.S., children must receive a diphtheria vaccine before they are allowed to begin school. It is often given in combination with other vaccines, like those for pertussis (whooping cough) and tetanus.
- If a person does contract diphtheria, antiboitics will destroy the diphtheria in the throat. The most important part of treatment is antitoxin, which kills circulating toxins that have not yet bound to tissue or mucus membranes.

Mystery Pathogen #4

I am a bacteria that normally lives in the intestines of birds and other animals. Sometimes I can get into the human stomach and intestines. I can survive stomach acid and digestive enzymes—in fact, I need these things to become active! I invade and kill the cells lining the intestines, called **epithelium**. Once this happens, the intestines become inflammed. The person I've infected gets a fever, severe stomach cramps, and diarrhea. Some doctors think I may also produce a poisonous substance called a **toxin**.

How can I infect the body?	How can the body defend itself?
Possible answers may include but are not limited to the following	
Infection strategies for the skin and respiratory tract are not applicable; this is a disease of the GI tract.	
Enter through contaminated food or water	
Attach to teeth	Lysozyme in saliva to break up and kill bacteria
Take advantage of reduced saliva	
	Peristalsis: contractions of the intestines do not allow bacteria to attach and grow; bacteria is pushed out of body
Attach to epithelial cells in the intestines with hooks/suckers/lock & key	Normal flora: outcompete bacteria for food or living space
	Stomach acid as defense does not work: this bacteria *needs* stomach acid
	Natural defenses: macrophage
Produce "slime capsule" to protect against macrophage action	
	Medication to neutralize toxin
	Normal flora: raise pH in stomach so that environment is not acidic enough
	Medication: antibiotic to kill bacteria

Real-life tidbits for teachers:

- This is *Salmonella enteridis*, the bacteria responsible for egg-associated salmonella (food poisoning).
- Prevention is the best cure for salmonella: make sure that eggs are stored, handled, and cooked properly.

Mystery Pathogen #5

I am a highly contagious virus that lives in the cells lining the nose and throat (the **epithelium**). I attach to and invade these cells, and interfere with the way they work. This kills the cells. A person infected with me (which happens especially in winter) gets a headache, fever, and cough. I can also affect other animals, including pigs and birds.

How can I infect the body?	How can the body defend itself?
Possible answers may include but are not limited to the following	
Enter through inhalation	Nose hairs and nasal turbinates to form physical barriers and prevent inhalation
Small size allows passage past nasal turbinates	
Attach to nose/throat epithelial cells with hooks/pili/lock & key, etc.	Use mucociliary elevator to trap virus and push it up and out of body
Destroy or slow cilia	
Break down mucus or use mucus as nutrient	
Outcompete normal flora	Normal flora may change pH to kill virus, or produce toxins
Enter through swallowing	Lysozyme in saliva breaks down virus
	Body’s natural defenses: alveolar macrophages kill virus
	Body’s natural defenses: immune response teches body to recognize and kill virus before infection progresses
	Normal flora may produce toxins that kill virus or outcompete virus for nutrients and living space
Avoid body’s natural defenses; produce ”slime capsule” to protect against macrophages	
	Medication to supress replication
	Medication to kill special virus or neutralize toxin
	Vaccine that allows body to recognize and destroy virus before infection progresses

Real-life tidbits for teachers:

- This is an influenza virus.
- Annual vaccination may help prevent influenza.
- Treatment for influenza includes rest, liquids, and fever reduction. Most people completely recover from influenza, unless their immune system has been compromised by another infection or condition.

Mystery Pathogen #6

I am a virus that crosses mucus membranes and invades the **epithelial** cells that line the nose and throat. I leave these cells and enter the bloodstream, which transports me to the other tissues and organs of the body. I cause a telltale rash, high fever, cough, runny nose, and watery eyes. Direct application of heat or light makes me harmless.

How can I infect the body?	How can the body defend itself?
Possible answers may include but are not limited to the following	
Enter through inhalation	Nose hairs and nasal turbinates to form physical barriers and prevent inhalation
Small size allows passage past nasal turbinates	
Attach to nose/throat epithelial cells with hooks/pili/lock & key, etc.	Use mucociliary elevator to trap virus and push it up and out of body
Destroy or slow cilia	
Break down mucus or use mucus as nutrient	
Outcompete normal flora	Normal flora may change pH to kill virus, or produce toxins
Enter through swallowing	Lysozyme in saliva breaks down virus
	Body's natural defenses: alveolar macrophages kill virus
	Body's natural defenses: immune response teches body to recognize and kill virus before infection progresses
	Normal flora may produce toxins that kill virus or outcompete virus for nutrients and living space
Avoid body's natural defenses; produce "slime capsule" to protect against macrophages	
	Medication to supress replication
	Medication to kill special virus or neutralize toxin
	Vaccine that allows body to recognize and destroy virus before infection progresses
	If it is known that a surface has come in contact with this virus, treating it with heat or light will render the virus inactive.

Real-life tidbits for teachers:

- This is the form of Morbillvirus that causes measles.
- Measles is easily preventable with a vaccine, which in the U.S. is usually given in childhood in combination with the mumps and rubella vaccines.
- Measles is treated with asprin or acetomenophin to reduce fever, bed rest, and a humidifer to soothe respiratory passages. Most people completely recover from measles. In rare cases, especially in malnourished children or in people with compromised immune systems, doctors administer antiviral medication.

Mystery Pathogen #7

I am a virus that enters through the mouth. I grow and divide in the nose, throat, stomach, and intestines. I invade lymph tissue and enter the bloodstream. I also infect the nervous system by traveling along nerve fibers. This destroys nerve cells—and once a nerve cell is detroyed, it can't grow back. This is how I can cause paralysis if left untreated. At first, I cause fever, headache, stomach ache, and stiffness in the neck, back, and legs. Heat, chlorine, and ultraviolet light can kill me.

How can I infect the body?	**How can the body defend itself?**
Possible answers may include but are not limited to the following	
Enter through inhalation	Nose hairs and nasal turbinates to form physical barriers and prevent inhalation
Small size allows passage past nasal turbinates	
Attach to nose/throat epithelial cells with hooks/pili/lock & key, etc.	Use mucociliary elevator to trap virus and push it up and out of body
Destroy or slow cilia	
Break down mucus or use mucus as nutrient	
Enter through contaminated food & water	Always wash hands before eating or preparing food
	Lysozyme in saliva breaks down virus
Attach to epithelial cells in nose, throat, stomach, intestines with hooks/suckers/lock & key	
	Stomach acid (high pH)
Create "slime layer" or "protective bubble" to protect against acid	
	Normal flora (outcompete virus or secrete toxin)
Outcompete normal flora or secrete substance to kill normal flora	
	Body's natural defenses: alveolar macrophages kill virus
	Body's natural defenses: immune response teches body to recognize and kill virus before infection progresses
Avoid body's natural defenses; produce "slime capsule" to protect against macrophages	
	Medication to supress replication
	Medication to kill special virus or neutralize toxin
	Vaccine that allows body to recognize and destroy virus before infection progresses
	If it is known that a surface has come in contact with this virus, treat surface with chlorine, heat, or UV light to kill virus

Real-life tidbits for teachers:

- This is the form of Poliovirus that causes polio.
- Vaccination has almost completely eradiacated polio in the Americas and most of Europe. Despite this, polio still affects a number of people in the rest of the world.
- Treatment in the early stages of the disease includes bed rest, isoluation, observation, and treatment of symptoms. Paralysis may be treated with special exercises that prevent deformity and increase strength in affected muscles.

Mystery Pathogen #8

I am a virus that can be found in the saliva of some raccoons, skunks, foxes, dogs, and bats. I can affect all mammals. Once I cross a person's skin, I can grow and divide in muscle tissue, or I can go directly into the nervous system. I travel along nerves, affecting nerve cells, tissues, and organs. A person infected with me may have a fever, headache, andeventually becomes confused, anxious, and delerious. If untreated, I cause brain damage and death.

How can I infect the body?	How can the body defend itself?
Possible answers may include but are not limited to the following	
Get into the bloodstream directly through a break in the skin when caused by a bite from an infected animal.	Avoid strange animals!
Respiratory/GI invasion strategies will not work—virus must be in bloodstream	
	Body's natural defenses: B cells & antibodies or vaccination teaches the body to "recognize" and destroy the virus
	Medication to block attachment of virus to nerve fibers. If it can't travel, it can't cause damage.
	Vaccine to teach body to recognize and destroy virus

Real-life tidbits for teachers:

- This is the virus that causes rabies.
- A routine rabies vaccination prevents animals (house pets, for instance) from contracting or transmitting rabies.
- When an infected animal (or suspected infected animal) bites a person, the person is treated with a series of anti-rabies serum injections that help the body kill the virus.

Mystery Pathogen #9

I am a bacteria found in the soil and in the intestinal tracts of animals. If I get through the skin of a person, I produce little structures called **spores** that release a poisonous **toxin**. These toxins block the brain from releasing important chemicals. Normally, these chemicals keep the muscles from unwanted movements. When I block the brain from releasing these chemicals, muscles contract uncontrollably. This leads to stiffness, muscle spasms, and sometimes "lockjaw." I cannot survive in the presence of oxygen, but my spores can survive most antiseptics and a lot of heat.

How can I infect the body?	How can the body defend itself?
Possible answers may include but are not limited to the following	
Get into the bloodstream directly through a break in the skin.	Protect broken skin
	Do not let virus get past skin: dryness, pH, sebum
	Normal flora: outcompete bacteria or secrete substance that makes environment unlivable
Respiratory/GI invasion strategies will not work—virus must be in bloodstream	
	Body's natural defenses recognize and destroy virus
	Medication to neutralize toxin
	Antibiotic to destroy bacteria
	Vaccine to teach body to recognize and destroy bacteria
	If it is known that a surface has come in contact with this bacteria, oxygenate area to kill bacteria

Real-life tidbits for teachers:

- This is *Clostridium tetani*, the bacteria that causes tetanus.
- The tetanus vaccine is highly effective in preventing the disease. It is given in early childhood, often in combination with the diphtheria and pertussis vaccines. In adulthood, boosters every five to ten years maintain the body's resistance to tetanus.
- Treatment for tetanus includes cleansing of the wound, neutralizing the toxin with antitoxin, reducing muscle spasm, and aiding respiration.

Other Websites of Interest

NASA Space and Life Sciences Directorate
http://www.jsc.nasa.gov/sa/index.htm

NASA Office of Biological and Physical Research
http://www.hq.nasa.gov/office/olmsa

NASA Life Sciences Data Archive
http://lsda.jsc.nasa.gov/

Biomedical Research and Countermeasures
http://www.hq.nasa.gov/office/olmsa/lifesci/biomed.htm

Human Physiology in Space, from the the National Space Biomedical Research Institute
http://www.nsbri.org/HumanPhysSpace/index.html